FINAL REPORT

ENERGY ENGINEERING
ANALYSIS PROGRAM
10th AREA SUPPORT GROUP

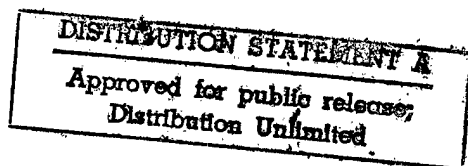### CONTRACT: DACA79-89-D-0023

VOLUME I

BUILDINGS

105/105A TORII STATION
200 TORII STATION
210 TORII STATION
214 TORII STATION
217 TORII STATION

PREPARED FOR:

DEPARTMENT OF THE ARMY
JAPAN DISTRICT, CORP OF ENGINEERS
ENGINEERING DIVISION,
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DECEMBER, 1990

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I. EXECUTIVE SUMMARY

A. Concept of the Study

The purpose of this study is to survey 11 of the major energy using buildings at Torii Station, Fort Buckner, and Naha Port to identify and evaluate Energy Conservation Opportunities (ECO's) based on Army economic standards.

B. Findings and Recommendations

A major program of Energy Conservation Projects is recommended. A thorough field survey of the buildings indicated great potential for energy savings as well as numerous humidity problems. Tables 1 and 2 summarize the Energy Conservation Opportunities which have been recommended for each building. This ECO package, when implemented, will result in a savings of approximately 10,167 MBTU/yr. At present energy costs this represents $132,432 annually. The total cost of these projects is $363,864, which produces an overall simple pay back of 2.7 years.

Detailed analysis of the ECO's indicates that in some cases it is possible to improve or even eliminate humidity problems with a project that saves a substantial amount of energy. Wherever possible, energy savings were used to justify modifications which would improve the space humidity levels. There were several cases, however, where the additional cooling energy needed to dehumidify properly offset any other energy savings which might have been achieved.

TABLE 1 - TOTAL PROJECT SAVINGS SUMMARY

BUILDING	ELECTRIC (KWH)	ELECTRIC (MBTUS)	FUEL OIL (GAL)	FUEL OIL (MBTUS)	TOTAL (MBTUS)	SAVINGS ($$$)	ECO COST ($$$)	PAY BACK
105/105A TORII	77,015	263	981	136.1	399	$6,544	$10,593	1.6
200 TORII	53,060	181	1,392	193.1	374	$4,618	$21,491	4.7
210 TORII	42,298	144	-9	-1.2	143	$3,473	$12,930	3.7
214 TORII	21,595	74	1,020	141.5	215	$2,175	$5,611	2.6
217 TORII	89,568	306	6,426	891.3	1,197	$11,040	$36,970	3.3
235 TORII	129,187	441	5,044	699.6	1,141	$16,575	$77,237	4.7
240 TORII	40,218	137	33	4.6	142	$4,591	$26,086	5.7
275 TORII	111,941	382	22,167	3,074.6	3,457	$22,211	$22,267	1.0
90 FT. BUCKNER	72,872	249	7,809	1,083.1	1,332	$10,176	$16,991	1.7
103 FT. BUCKNER	371,393	1,268	0	0.0	1,268	$33,072	$99,273	3.0
305 NAHA PORT	146,946	502	-6	-0.8	501	$17,957	$34,415	1.9
	1,156,093	3,946	44,857	6,222	10,167	$132,432	$363,864	2.7

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TABLE 2 - QUALIFYING PROJECTS CHECKLIST

ECO	TORII 105/105A	TORII 200	TORII 210	TORII 214	TORII 217	TORII 235	TORII 240	TORII 275	FB 90	FB 103	NAHA 305
DUTY CYCLE FANS	X	X			X					X	
HEATING SHUTDOWN	X										
REDUCE OSA	X										
DHW PUMP TIMECLOCK	X	X		X	X	X			X		X
ENERGY EFF. FLUOR.	X		X			X		X			
INT. KIT. MUP/EXH.		X									
MOTION SENSORS		X	X	X	X				X		X
OSA CUTOFF FOR HTG.		X		X	X				X		
FLUOR. RETROFIT		X			X	X					
TWIST TIMERS			X				X	X	X		
NIGHT SETBACK			X							X	X
AUX. CLG. EQ. MODS.				X							
SHOWER FLOW RESTRICTORS					X	X		X	X		
SZ UNITS TO VAV							X				
MORE EFF. LTG. FIXTURES							X				X

ENERGY ENGINEERING ANALYSIS PROGRAM (EEAP)
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OKINAWA, JAPAN

TABLE 2 - QUALIFYING PROJECTS CHECKLIST

ECO	TORII 105/105A	TORII 200	TORII 210	TORII 214	TORII 217	TORII 235	TORII 240	TORII 275	FB 90	FB 103	NAHA 305
SOLAR FILMS							X	X			
RESET CHW TEMPERATURE				X				X			
TURN OFF HTG. COIL								X			
REFR. HEAT RECOVERY								X			
FAN CONTROL MODIFICATIONS									X		
WEATHERSTRIPPING									X		
CONVERT DX TO CHW										X	
PHOTOCELLS											X

II. INTRODUCTION

A. Prefinal Report

It is the purpose of this report to present the work carried out to date for the project Energy Engineering Analysis Program, 10th Area Support Group, under A/E Contract: DACA79-89-D-0023, Delivery Order #0004, by the Joint Venture contractor Gushiken Architectural Engineering Co. LTD/Engineering Sciences, Inc.

The work consists of the discovery and development of economically and technically attractive Energy Conservation Opportunities (ECO's) to reduce the energy consumption of 11 buildings located at the U.S. military installations, Torii Station, Ft. Buckner, and Naha Port, Okinawa, Japan. To accomplish this task, a full energy audit was performed for each of the facilities, in order to explain existing energy use patterns. Once the BASE CASE energy use was determined, a comprehensive list of ECO's was considered. After elimination of those potential ECO's that would be inappropriate or impractical for the facility, some eliminated from experience and some from preliminary analysis, the remaining ECO's were analyzed in detail.

B. Buildings Surveyed

As specified in the Scope of Work, the following buildings were studied:

Torii Station	Ft. Buckner	Naha Port
105/105A	90	305
200	103	
210		
214		
217		
235		
240		
275		

These buildings total approximately 443,000 Sq.Ft. of floor area and are cooled by approximately 1640 tons of air conditioning equipment. The annual existing energy costs for these buildings totals approximately $ 1,100,000.

C. Government Individuals Contributing to this Study

Government individuals contributing to this study include:

J. Joseph Tyler, P.E.; Chief Engineer Liaison Branch
John A. Romeo, P.E.; Chief, Military Section
Wendell S. Awada, P.E.; Chief, Design Section
Richard McEwen; CEPOJ-ED-OM Project Manager
John Angell; Department of Engineering and Housing

III.   Methodology

A.   Field Survey

During October 1989, the contractor's field survey team visited the facilities to gather information about the buildings and energy using equipment.   Items that were specifically addressed are:

1.   Review of Plans and Specifications

To the extent they were available, building plans and specifications were collected by the contractor's survey team during the field survey.   This information was reviewed during the individual building surveys for accuracy when compared against actual "as observed" conditions.

2.   Existing and Proposed Projects

The contractor was provided with information about existing and proposed projects which might alter the "as observed" condition of the buildings and equipment, and these were taken into account in the conduct of the study.

3.   Personnel Interviews

Knowledge of current operating practices was essential to the success of this study.   For this the contractor relied upon station and maintenance personnel for orientation and insight.   Every effort was made to take full advantage of this knowledge without losing perspective or overview.

4.   Building Surveys

In performing this portion of the work the contractor made on-site inspections and measurements of each building and its equipment. The data collected were compiled on field survey forms prepared for this purpose. All testing and measurement equipment was properly calibrated prior to its use.   Particular attention was given to:

a.   Verifying building dimensions, window and wall areas, and construction materials.

b.   Determining the functional use of the building and the hours of operation.

c.   Obtaining actual room temperatures (dry and wet bulb).

d.   Measuring actual discharge air temperatures and air flow rates or pressures where possible.

e.   Measuring voltage, amperage and instantaneous power requirements and power factors on pumps, exhaust fans and air handling units.

f.   Measuring space light levels and noting lamp wattages as well as the

number of fixtures in use.

g. Inspecting all HVAC equipment and control systems to discover normal operating strategies and deficiencies.

h. Fully field testing the operational efficiency of all boilers.

i. Indentifying potential ECOs and measuring any variables necessary to for their analysis.

At the end of each days work the members of the field survey team met to discuss particular problems and proposed modifications and solutions. These discussions aided the survey team in fully understanding the systems.

B. Analysis

1. Building Evaluation

The initial efforts of the analysis are to fully understand the operation of each piece of major equipment. To this end, equipment manufacturers and suppliers were contacted to obtain operational data and performance specifications of all major equipment possible. With this information, the actual measured conditions obtained during the field survey were analyzed. The results were than compared to design requirements which provided a method of evaluating the operational performance of this equipment.

2. Idealizations

In order to analyze energy consuming HVAC equipment, it is first necessary to understand the operating strategy. This information can be collected during the field surveys. It was often found, however, that much of the equipment is operated manually by the maintenance personnel or building occupants. This can usually be seen in such items as moving thermostats as ambient conditions change, turning off equipment during mild seasons or turning off some equipment at night. Two points are important in this regard: 1) the contractor is often forced to rely upon the operator's account of how he runs the building, and 2) manual control of equipment is specialized and almost impossible to model. With these limitations in mind, the contractor has assembled the best available information of building operation and made only those simplifications necessary to make analysis possible.

3. BASE CASE Analysis

The review and analysis of the field data provided a data base for the energy audit of the buildings. The existing annual energy usage of all significant energy using equipment was calculated. For some types of usage, the calculations are very straightforward and simple spreadsheets readily display the full calculations. For others, the usage is more complicated and spreadsheet calculations are supported by supplemental calculations which are displayed to explain some of the input for the spreadsheet. The

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spreadsheets are laid out so that the logic is self-evident as much as possible.

Accurately calculating a building's annual cooling energy and heating energy is not a simple process. Several methods are available which result in approximations of energy use. Some very simple methods are available, but result in very rough approximations that sacrifice accuracy for speed and ease of use. Methods of this type include graphical interpretation of utility bills, the Equivalent Full Load Hour (EFLH) Method, and Cooling and Heating Degree Day Methods.

On the other end of the scale are methods that are very time consuming, difficult to use and understand, and supposedly offer more accurate estimations. Hour-by-hour annual computer simulations of energy use such as BLAST, DOE-2, ASEAM, TRACE, etc. fall into this category. While use of these programs may be required in certain complicated situations, these massive computer programs are very error-prone due to the complexities involved. It has been the experience of ESI and most others experienced in energy calculations, that the best results are achieved if a method is chosen which is a compromise -- sophisticated enough to be accurate, but not so complicated as to be very difficult to use.

A very good compromise in accuracy, speed, and adaptability is the commonly used Bin Method described in ASHRAE handbooks. The Bin Method consists of performing an instantaneous energy calculation at each of many different outside air (OA) dry bulb (DB) conditions, and multiplying the results by the number of hours of occurrence of each condition. In other words, instead of breaking the year up into 8760 hours and then calculating the energy use for each hour and summing up (the method used by the complicated programs indicated above), this method breaks the year up into a manageable and understandable number of weather bins for each month and for each period of the day. This method accounts for the part load performance of Heating, Ventilating, and Air Conditioning (HVAC) equipment.

The basic Bin Method can be improved to allow more flexible consideration of internal loads due to lights, people and equipment, plus building envelope heat losses or gains based on an indoor space temperature and average solar gains. The use of Mean Coincident Wet Bulb (MCWB) temperatures to calculate the latent loads at each temperature bin further enhances the program's accuracy. This latter refinement is significant, and especially for a tropical climate like Okinawa. Such refinements to the basic Bin Method are described in the 1983 ASHRAE publication, Simplified Energy Analysis Using the Modified Bin Method.

ESI has incorporated the refinements (and more) into its Annual Energy Utilization Programs (AEUPs). These AEUPs are computerized versions of the Modified Bin Method developed for use on computer spread sheets, and come in several versions (like HVAC Systems do); Single Zone (SZ V2.2), Single Zone with Stratification Option (SZS V1.9), Constant Volume with Reheat (CVRH V3.1), Multi Zone (MZ V1.5), Multi Zone with Texas Bypass (MZTX V1.7), Variable Air Volume with a Forward Curve fan and Inlet Guide Vanes (VAVFCIGV

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V6.6) and various other Variable Air Volume (VAV) Versions. A copy of one example of the program is shown on the following page.

The input for the analysis is found in the first 8 blocks. The output (results) is found in block 9. A brief description of each input block:

Block-1. This block contains information to describe the building envelope. Inputs include roof and floor areas as well as wall and window areas for each of four compass directions. Also described are the heat transfer properties of the envelope components including U-factors, shading coefficients, and absorptivities. All these inputs must be measured and calculated separately prior to input by the user.

Block-2. This block contains information to describe the heating and cooling equipment, its capacity and efficiency.

Block-3. This block contains input to describe the internal heat gains to the building from such sources as people, lights, AHU fans, and miscellaneous sources.

Block-4. This block quantifies the loads on the building from outside air sources, both infiltration and ventilation. These loads are especially important in the humid climate since they represent major latent loads. Also input in this block is the supply air quantity of AHU's.

Block-5. This block allows the user to flexibly describe variations of internal heat gains depending on the period of the day or whether its a weekday or weekend day. The first column is the night shift (hour 1 through hour 8); the second, the day shift (hour 9 through hour 16); the third, the evening shift (hour 17 through hour 24).

Block-6. In this example version of the program, analysis of the effects of stratification is possible, and is input in this block. Tall spaces typically experience stratification of temperatures on the order of 0.5 to 1.0 deg F per foot of height (depending on the manner of air circulation in the space).

Block-7. This block allows the user, by inputting a zero, to prohibit the program from counting any cooling or heating done in a particular month. If it is known that a facility does not use its cooling equipment in a certain month for example, regardless of load, this lockout can be used.

Block-8. This block allows the user to specify the average temperature maintained in the building for any shift for any month. Thus different thermostat setpoints can be used in summer vs. winter, day vs. night, etc.

The essence of the program operation is as follows. The year is divided up into "bins"; each representing a group of hours that the building spends at

a certain outdoor temperature. Each bin spans 5 deg F. Thus one bin might be all the hours the building experiences when the outdoor air temperature is between 85 and 89 deg F. This bin would be represented by the average temperature of 87 deg F.

Further each bin is divided up into three periods or shifts and into 12 months. What results is a multi-dimensional matrix or grid of conditions, representing all the combinations of bins, months, and shifts. Each cell in that matrix contains the number of hours the building spends facing that combination of conditions. The program simply goes through this matrix, one cell at at time, and calculates the heating or cooling load on the building when it's in that cell, and then calculates the energy use for meeting those loads for all the hours in the cell. At the end the program sums all the heating and then all the cooling done in all cells, and the result is the annual heating and cooling energy spent by the building.

As an example of how the program works consider a typical cell, say the 87 deg F bin, day shift, June. This particular cell chosen for illustration happens to have 67 hours in it, i.e. there are 67 hours in Okinawa, in June, during the day shift, when the outdoor temperature is between 85 and 89 deg F. The program then calculates the amount of heating or cooling the building HVAC systems must do, for the conditions of that cell, to meet the indoor conditions specified, for one hour. Then it multiplies that amount by 67.

Prior to using the program the user must input the (not shown on the input/output report) both the annual bin weather data for the location and the annual solar data, describing the solar gains through walls, roof, and windows for each direction.

For the one hour being considered the program first calculates all the loads on the space. This occurs using the information from the input blocks described earlier. In June there will be a cooling load. Setting parameters of building operation in Blocks 5,6,7, and 8, Block 1 determines the heat gains through the building envelope, calculating wall, roof, floor, and window transmission gains as well as solar gains. Heat gains due to people, lights, fans, equipment, and outside air (both sensible and latent) are calculated using information in Blocks 3 and 4. The sum of all these gains determines the total cooling load on the space. (In a cooler month these might sum to a negative number indicating a heating load.) Using Block 2, the program then converts the cooling load for the hour to a cooling energy use using information input about the size and efficiency of HVAC equipment. The cell calculation is finished when the program multiplies the hour's energy use by 67.

The program then sums up with the energy use for all cells to determine the annual totals. In a similar fashion the program also calculates and keeps up with the lighting and HVAC fan energy use for the year. The results are printed out in Block 9.

The energy savings for a myriad of Energy Conservation Opportunities (ECO's)

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can be calculated by modifying the input blocks, and comparing the "before and after" results. For example, building envelope changes like wall insulation or solar film, etc. can be analyzed by changing the U-factor or shading coefficient in Block 1. Savings from lighting efficiency improvements (both in the lighting energy directly, and in cooling and heating energy indirectly) can be analyzed by changing Block 3. Changes such as setback or shutoff of HVAC equipment when the building is unoccupied can be modeled with changes in Block 8. These are a few examples of the numerous ECO's that can be analyzed by the program.

ESI has used this Modified Bin Method in many, many buildings to predict energy savings. In a number of buildings the actual energy use, before and after ECO's use has been obtained to verify the accuracy of predictions and build confidence in the program. It is the opinion of ESI that, all things considered, this method was the best available for this study.

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****************************************************************************************
*                                                                                    *
*                    ANNUAL ENERGY UTILIZATION PROGRAMS (AEUPs)                       *
*                           ENGINEERING SCIENCES, INC.                                *
*                 MEMPHIS, TN, USA  ***  GINOWAN CITY, OKINAWA, JAPAN                  *
*                                                                                    *
*               PROGRAM: SZS V1.9 (SINGLE ZONE WITH STRATIFICATION OPTION)            *
*                                                                                    *
****************************************************************************************
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>BLOCK 1<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
**********************************BUILDING/ZONE DESCRIPTION AND CONSTRUCTION*************
*                                                                                    *
*              BUILDING: ***building # camp name***, OKINAWA, JAPAN                   *
*                   ZONE: # (***zone description***)                                  *
*                                                                                    *
****************************************************************************************
* ROOF AREA          =  10,000       ROOF ABSORPTIVITY   =   0.15     ROOF U-FACTOR =  0.100 *
* WALL AREA:  NORTH =   1,000        WINDOW AREA:  NORTH =   100      FLOOR AREA    = 10,000 *
* (GROSS)     SOUTH =   1,000                      SOUTH =   100                             *
*             EAST  =   1,000                      EAST  =   100                             *
*             WEST  =   1,000                      WEST  =   100                             *
* WALL ABSORPTIVITY   =   0.15       WINDOW SHADING COEFF. =  0.75                           *
* WALL U-FACTOR       =   0.20       WINDOW U-FACTOR     =   1.10                            *
****************************************************************************************
>>>>>>>>>>>>>>>>>>BLOCK 2<<<<<<<<<<<<<<<<<<   >>>>>>>>>>>>>BLOCK 3<<<<<<<<<<<<<<<   >>>>>>>>>>BLOCK 4<<<<<<<<<<<<
************COOLING***************HEATING*****   **************INTERNAL**************   **********AIR FLOW**********
* ENTHALPY       =   30.0 HTG EF=  0.75 *  * LIGHT (WATTS)      =  10,000 *  * INFILTRATION  =  1,000 *
* CLG EQ COP     =    2.0 F. OIL= 138,750 *  * NO. PEOPLE         =      10 *  * SUPPLY AIR    = 10,000 *
* COIL SENS CAP  = 75,000                 *  * FAN KW             =    1.00 *  * VENTILATION AIR=     0 *
* COIL TOT CAP   = 100,000                *  * MISC SENS (KW)     =    0.00 *  *                        *
*                                         *  * MISC LAT           =    0.00 *  *                        *
****************************************   **********************************   ***************************
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>BLOCK 5<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<   >>>>>>>>>>>BLOCK 6<<<<<<<<<<<<<<
****************************SHIFT MULTIPLERS***************************   **********STRATIFICATION**********
*              *WEEKDAY                    *WEEKEND             *   * ROOM HEIGHT              10.00 *
*           0108   0916   1724        0108   0916   1724 *   * EXHAUST HEIGHT            9.00 *
* LIGHTS     0.00   1.00   0.00        0.00   0.00   0.00 *   * EXHAUST (CFM)             200 *
* PEOPLE     0.00   1.00   0.00        0.00   0.00   0.00 *   * STRAT. DELTA                  *
* EQUIPMENT  1.00   1.00   1.00        1.00   1.00   1.00 *   * TEMP (F)                 2.50 *
*********************************************************************   **********************************
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>BLOCK 7<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
***************************MONTH-BY-MONTH HEATING AND COOLING LOCKOUT*******************
*       MONTHS:    JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP   OCT   NOV   DEC *
* HEATING     =      1     1     1     0     0     0     0     0     0     0     1     1 *
* COOLING     =      0     0     0     1     1     1     1     1     1     1     0     0 *
****************************************************************************************
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>BLOCK 8<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
***************************SPACE CONTROL TEMPERATURES**********************************
*       MONTHS:    JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP   OCT   NOV   DEC *
* 0100 - 0800 HRS=  70    70    70    75    75    75    75    75    75    75    70    70 *
* 0900 - 1600 HRS=  70    70    70    75    75    75    75    75    75    75    70    70 *
* 1700 - 2400 HRS=  70    70    70    75    75    75    75    75    75    75    70    70 *
****************************************************************************************
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>BLOCK 9<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
***********************ANNUAL ENERGY UTILIZATION PROGRAM RESULTS***********************
* HEATING COOLING LIGHTING FAN * * ————  —————————  ————  ———— * * TOTAL LOAD (million BTUs) = 57.285
MBTU  342.392  MBTU  * * TOTAL  UTILITY  =   550   GAL.  50,160  KWH  20,857  KWH  8,760  KWH  *
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4. ECO Analysis

In carrying out a study of this type, it is important that every conceivable ECO be considered. To aid in this attempt, a list was developed by the contractor incorporating the 41 recommendations required in the Scope as well as additional items deemed appropriate by the contractor. This checklist was used to encourage the thoroughness desired for each building.

After identifying the appropriate ECOs for each facility, savings and cost estimates were prepared. At this Interim Report, ECOs have been analyzed independently, i.e., not taking into account overlapping savings among ECOs. For the next submittal, ECOs will be ranked according to Savings to Investment Ratio (SIR) and then re-analyzed taking synergism into account.

A number of ECOs that might be attractive, and in some cases are usually attractive, at other geographical locations, are either not economically attractive or not technically feasible in the humid tropical climate in Okinawa. The temperature swings in the tropics are not nearly as great as in more polar latitudes. For example, most of the continental U.S. experiences average daily temperature swings of 20 degrees F or greater and annual swings of high nineties to sub-freezing and even sub-zero. In Okinawa the average daily swing is 10 degrees F and the annual swings are generally high eighties to high forties. Not only is the heating season quite abbreviated, but the overall loading profile is flattened.

The following ECOs, usually not applicable in Okinawa except in unusual situations, are briefly discussed:

a. Wall insulation - retrofit costs of wall insulation are much greater than insulating a wall as part of building a new building. This ECO can marginally be justified in locations with temperature extremes, particularly an extended heating season. This ECO was attempted for one of the buildings in this Scope having the best chance for being attractive, and the simple payback was found to be 36 years.

b. Roof insulation - this ECO is in the same category as wall insulation, except that the paybacks tend to be somewhat shorter, but not attractive.

c. Insulating glass/double glazing - again this is only marginally attractive in northerly climates with extended cold weather. This ECO was attempted in one building and the payback was found to be 107 years.

d. Insulated panels - same as wall insulation above.

e. Reduce glass area - With mild dry bulb temperatures, the conduction/convection improvements associated with a lower U-factor for wall versus glass cannot justify the high cost of the retrofits.

f. Reduce air stratification - this ECO applies to high-ceiling areas in winter climates, both of which were generally absent for this project.

The persistent high humidity in Okinawa causes severe HVAC problems ranging from uncomfortably high space relative humidities in almost every building, condensation problems, mold and mildew growth, and others. Many of these problems are exacerbated by inappropriate design of the air conditioning systems and especially the controls, a number of times the worst possible

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choices being the ones chosen. The high latent loads render some of the conventional ECOs for other climates, inappropriate for the tropics.

The following ECOs are not applicable to buildings in the humid climate:

a. Chilled Water Reset – raising chilled water supply temperature increases compressor efficiency and saves energy and is an attractive ECO in drier climates, especially with larger machines. It is completely inappropriate in the humid climate, leading to loss of dehumidification and greatly exacerbating the building humidity problems enumerated above. Many buildings in Okinawa have elevated chilled water supply temperatures and this destructive measure should be discouraged at all cost.

b. Reduce Outside Air (without simultaneous reduction of exhaust air) – while reducing outside air from entering a building would seem to reduce the amount of moisture entering the building, there is a contradiction. If one reduces ventilation air at the AHU and does not simultaneously reduce exhaust air, one increases infiltration into the space by lowering the positive pressurization or increasing the negative pressurization in the building. While the increased infiltration is less than the reduced ventilation air, and thus energy is saved, the infiltrated air directly enters the space laden with moisture (without passing through a cooling coil like the ventilation air), significantly increasing space humidity levels and the related humidity problems. Reduction of excessive ventilation quantities should always be accompanied with reductions in exhaust quantities.

c. Economizer – it can be shown that using 100% outside air for cooling in Okinawa can be beneficial for so few hours (because of the high moisture content), that the additional cost and complexity can never be paid back.

A number of other ECOs were considered that were not appropriate for any of the 11 buildings included in this study. They are discussed below:

a. Add duct insulation – all ducts were found to have sufficient insulation.

b. Add vestibules – buildings either had vestibules or were not leaky. In tight buildings, vestibules can only be justified in the cold climate.

c. Add load dock seals – only one building had loading docks and air curtains were being used to reduce infiltration.

d. Radiator controls – none of the building had radiators.

e. Reduce air flow – none of the buildings had AHU's whose air flow was measured to be excessive.

f. Boiler oxygen trim controls – in this climate these buildings had small boilers which are well maintained and had relatively high operating efficiencies in every case. Relatively expensive oxygen trim controls can only be justified with much greater heating energy use.

g. Revise boiler controls – none of the boiler's controls were identified

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to be causing significant energy waste.

h. Chiller replacement - Normally can only be justified in an unusual case of either an extremely inefficient machine (which was not present in these buildings), or when fuel cost relationships make it attractive to switch chiller types, e.g., from absorption to electric.

i. Domestic hot water heat pumps - this ECO was investigated and it was found that because of the very high electricity in Okinawa, that there were no savings possible; heating hot water with fuel oil is cheaper than with a heat pump.

j. Waste heat recovery - no sources of significant waste heat were identified (note: this does not include refrigerant heat recovery from air conditioning compressors, which was considered as an ECO).

k. Instantaneous hot water heating - this is only possible in a situation of very high storage heat losses, not found in any of these buildings.

l. Air curtains - no buildings were found with continuously openings.

m. Reduce fan pressures - no AHU's were measured to be operating at excessive fan pressures.

n. Heat recovery from exhaust - no high temperature exhausts were present in these buildings.

o. Eliminate duct leaks - no significant duct leaks were detected.

p. Reduce chilled water flow - no pumps were found pumping excessive chilled water flow. the costs of conversion to variable

q. Fix steam/water leaks - none found.

r. Convert to variable chilled water flow - chilled water systems were not large enough to justify the high costs of conversion to variable flow.

s. Eliminate hot gas bypass - none found.

t. Transformer loading - transformer efficiency even at 25% load is as high as full load efficiency. The only time transformers can be replaced for energy reasons is if the transformer is so oversized that it never loads more than 20% and it spends most of its time loaded 10% or less. This would usually only occur in unusual circumstances, e.g. if a building with an intense electrical load lost the load for some reason (like changing the basic use of the building). None of the buildings in this study had severely oversized transformers.

One other ECO deserves special mention. While no situations were found where immediate replacement of standard efficiency motors with high efficiency motors could be justified, it is nevertheless recommended that anytime a new motor is purchased for a replacement, the high efficiency type should be selected; i.e., the incremental additional cost of the more efficient motor has an attractive payback, while wholesale replacement of working motors is not.

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C. Utility Costs

1. Electric Rates

a. Energy Charges

The savings which will result from saving a kilowatt hour of electricity (i.e., the "incremental" rate) has been determined by weight averaging the "Summer Season" rate (1 July through 30 September = three months) with the "Other Season" rate (1 October through 30 June = nine months). The resulting annual rates are:

Naha Port: 16.59 Yen/KWH

Torii Station/Ft. Buckner: 10.05 Yen/KWH

b. Demand Charges

The situation for demand savings is somewhat more complicated. All demand charges are based upon the "Contract Demand." The rates for contract demand are:

Naha Port: 1,575 Yen/KW-MO

Torii Station/Ft. Buckner: 1,730 Yen/KW-MO

Determining the impact on demand charges from a reduction in contract demand is dependent upon negotiations between the customer and OEPC. The rate schedules say that "Contract demand shall be determined through *consultation* between the customer and the Company on the basis of connected load, customer's transformer station, the load factor and operational conditions of similar classes of business." In practice it appears that *consultation* in effect means that a twelve month ratchet is imposed and that every time the Actual Demand for a month exceeds the Contract Demand, the Contract Demand is adjusted up to the new higher value. Cases have also been seen where Contract Demand, on a feeder with falling Actual Demand, is negotiated downward.

With this viewpoint the study has assumed that anything that is done to save a KW of demand is a benefit to the customer in that the upward negotiation is less or, even, that a downward negotiation will take place. In any event, the effect of the twelve month ratcheting means that, if you can cut a KW of demand and hold this level or less throughout the year, you will save twelve times the numbers shown above. Therefore, the demand savings are:

Naha Port: 18,900 Yen/KW-YR

Torii Station/Ft. Buckner: 20,760 Yen/KW-YR

c. Power Factor Charges

The customer is charged for going below a power factor of 0.85 at a rate of 1% for each 1% he goes below. Similarly, if the customer exceeds the 0.85 target, he gets a credit computed in the same manner. In fact, the combined (Torii Station and Naha Port) bills for the twelve months ending September 1989 show a small power factor credit. This, however, was only 1.8% of the total net bill and has been

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ignored in all of the calculations of this study.

2. Fuel Oil Costs

As instructed by CEPOJ-ED-OM, fuel oil cost of $0.65 per gallon was used in the analysis.

D. Exchange Rate

An exchange rate of 140 Yen per one U.S. dollar has been used throughout this study.

E. Weather Data

In conducting the analysis, the contractor has used bin date for Kadena Air Base, Okinawa, Japan, as published in Engineering Weather Data (NAVFAC P-89).

F. Economics

The updated ECIP guidance effective April 1988 was used in calculation of all savings to investment ratios (SIRs). The uniform present worth (UPW) factors utilized for energy savings are shown in Table 1 below (based upon a discount rate of 7% and using the United States average figures):

Project Life (Years)	Electricity	Fuel Oil
1	0.93	1.01
2	1.79	1.98
3	2.58	2.90
4	3.31	3.79
5	3.99	4.66
6	4.62	5.51
7	5.22	6.34
8	5.77	7.17
9	6.29	7.99
10	6.79	8.80
11	7.26	9.58
12	7.71	10.34
13	8.12	11.06
14	8.51	11.74
15	8.88	12.39
16	9.22	13.00
17	9.54	13.58
18	9.85	14.12
19	10.13	14.63
20	10.39	15.11
21	10.64	15.57
22	10.87	15.99
23	11.09	16.39
24	11.29	16.77
25	11.48	17.13

Table 1

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Based on SOW, these Energy Studies are unclassified/unlimited.
Distribution A. Approved for public release.

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